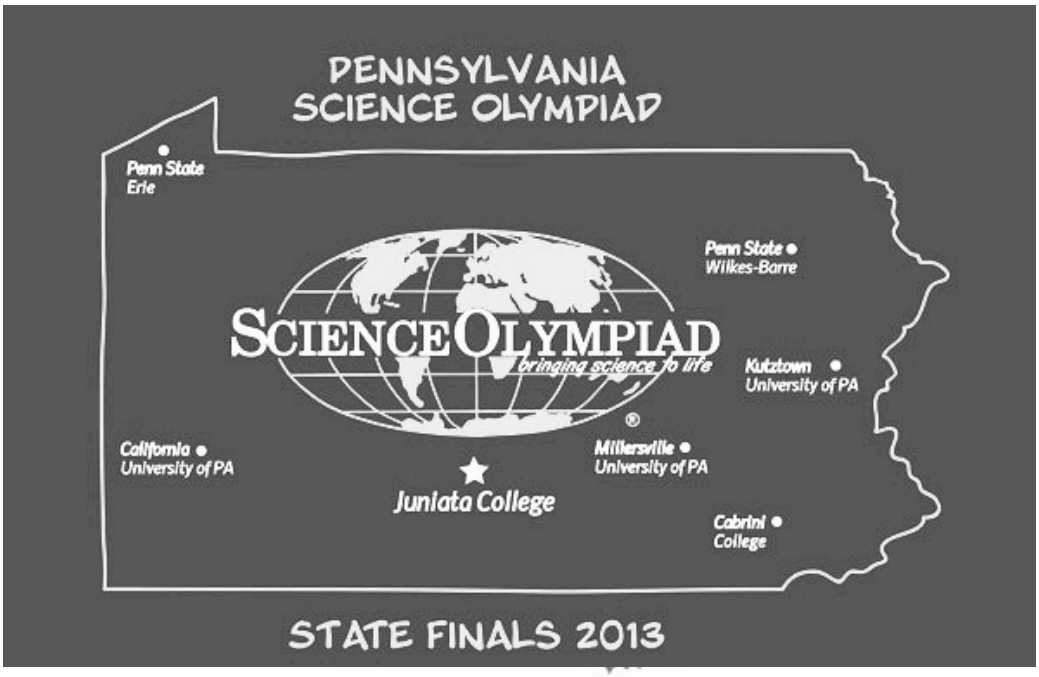
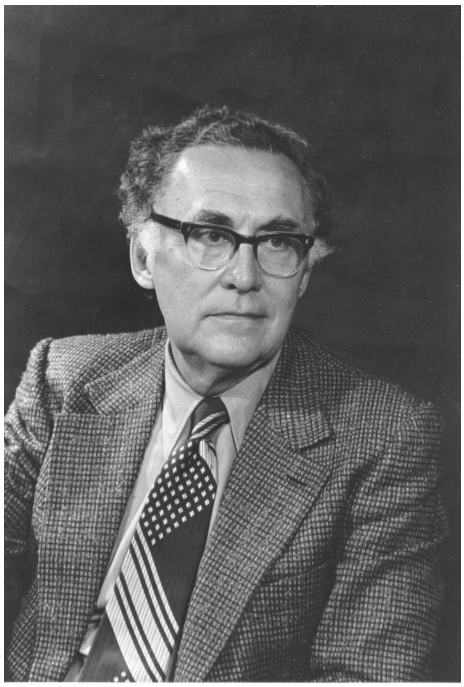


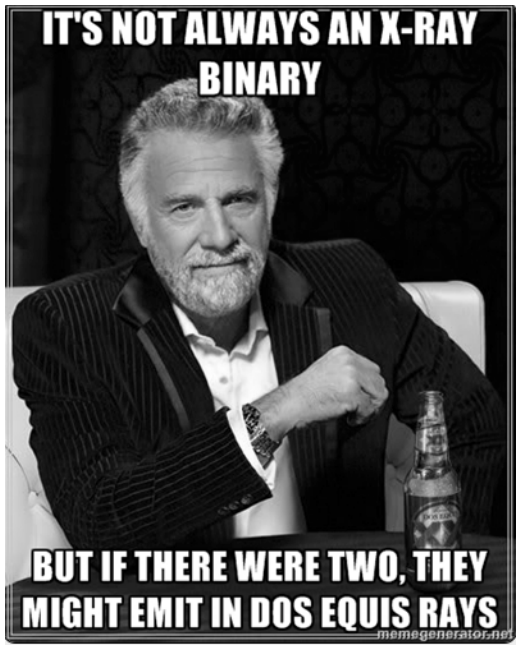
PENNSYLVANIA SCIENCE OLYMPIAD

STATE FINALS 2013

ASTRONOMY C DIVISION EXAM

APRIL 26, 2013





TEAM NUMBER _____ SCHOOL NAME_____

INSTRUCTIONS:

1. **Turn in all exam materials at the end of this event. *Missing exam materials will result in immediate disqualification of the team in question*. There is an exam packet as well as a blank answer sheet.**

2. **You may separate the exam pages. Submit the answer sheet separately.**

3. ***Only* the answers provided on the answer page will be considered. Do not write outside the designated spaces for each answer. Illegible responses are incorrect. You may write in the exam booklet.**

4. **Include school name and school team number at the bottom of the answer sheet as well as on the title page. Indicate the names of the participants *legibly* at the bottom of the answer sheet. Be prepared to display your wristband to the supervisor when asked. *If you do not have a wristband, you may not participate.***

5. **Each question is worth one point. Tiebreaker questions are indicated with a (T#) in which the number indicates the *order of consultation* in the event of a tie. Tiebreaker questions count toward the overall raw score, and are only used as tiebreakers when there is a tie. In such cases, (T1) will be examined first, then (T2), and so on until the tie is broken. There are 15 tiebreakers.**

6. **Pay close attention to the units given in the problem and the units asked for in the answer.**

7. **When the time is up, *the time is up*. Continuing to write after the time is up risks immediate disqualification.**

8. **Nonsensical, mocking, or inappropriate answers WILL RESULT IN DISQUALIFICATION.**

9. **In the bonus box on your answer sheet, indicate the name of the gentleman shown in the image on the *lower left side* of the cover sheet. The most interesting man in the world will not earn you the bonus.**

Questions numbered 1-42 refer to image page 1, image page 2, and the object list as published in section 3c of the Astronomy rules in the 2013 Science Olympiad Student Manual.

1. **Which image on image page 1 shows the Crescent Nebula?**

2. **(T4) What is this object's designation in the Caldwell Catalogue?**

3. **What is the type and designation for the object responsible for the ionization of the Crescent Nebula?**

4. **Which image shows a portion of the remnant of a supernova observed in 1054 AD?**

5. **Recently this object was seen to emit extremely high-energy pulsed gamma radiation. What is the unexpectedly high energy level of these gamma rays?**

6. **Which image on image page 2 shows the light curve from the object referred to in question #4?**

7. **One of the objects on the list experienced an unusual series of brightening and dimming events starting in early 2002. Since then it has evolved rapidly. Which image on image page 1 shows this object?**

8. **Which image on image page 2 shows the light curve demonstrating the unusual outburst associated with the object referred to in question #7?**

9. **What phenomenon continues to illuminate the dust around this object, providing observers the opportunity to accurately determine the distance to this object?**

10. **One of the images on image page 1 shows an active region of the SMC where stellar formation is taking place; recent type II supernovae in this region have interacted with the interstellar medium to produce interesting effects. Which image shows this region?**

11. **What is the name for the phenomenon created by the overlapping envelopes of gas and dust?**

12. **Name one of the supernovae responsible for this phenomenon in this object.**

13. **Another image on image page 1 shows an object from the SMC. Which image is it?**

14. **What is the designation for the object referred to in question #13?**

15. **(T6) What is odd about this object?**

16. **Consider image 8 on image page 1. Which object from the list is shown in image 8?**

17. **Which image on image page 2 shows the light curve for the object referred to in question #16?**

18. **Another image on image page 1 shows a region in the very near vicinity of the object in image 8. Which image is it?**

19. **What is the Index Catalogue designation for the nebula surrounding the star that gives this region its name?**

20. **One of the images shows the prototype for a particular type of pulsating variable star. Which image is it?**

21. **What is the Bayer designation for the object referred to in question #20?**

22. **(T11) What is the Henry Draper Catalogue number for the object referred to in #20?**

23. **One of the images on image page 1 shows a type II supernova that was found to be roughly 10 times more energetic than a typical type II. Which image is it?**

24. **Which image on image page 2 originated with this object?**

25. **In what galaxy was this supernova discovered?**

26. **(T15) One of the images shows a variable star of classification SRc. Which image is it?**

27. **Which image on image page 2 corresponds with the object referred to in question #26?**

28. **Which of the objects on the list created the light curve shown in image 17 on image page 2?**

29. **What is notable about the object referred to in question #28?**

30. **Consider image 6 on image page 1. What is this object's designation in the Third Cambridge Catalogue of Radio Sources?**

31. **In what constellation does this object appear in the night sky?**

32. **What is indicated by the straight, dark lines superimposed on the image?**

33. **One of the images on image page 1 shows part of an emission nebula in the constellation Cepheus. Which image is it?**

34. **What is the Henry Draper Catalogue number for the star illuminating the object referred to in question #33?**

35. **(T8) Which of the images on image page 1 is of an object that appears in the constellation shown below?**

36. **Which image on image page 2 corresponds to the object referred to in question #35?**

37. **The emission similarities between objects of this type (referred to in question # 35) and active galactic nuclei have spawned a name for this class of objects. What is this designation?**

38. **The object referred to in question #35 is part of a binary system, which is in turn part of a larger group of stars. What is the name of this group? (it is not the constellation shown above).**

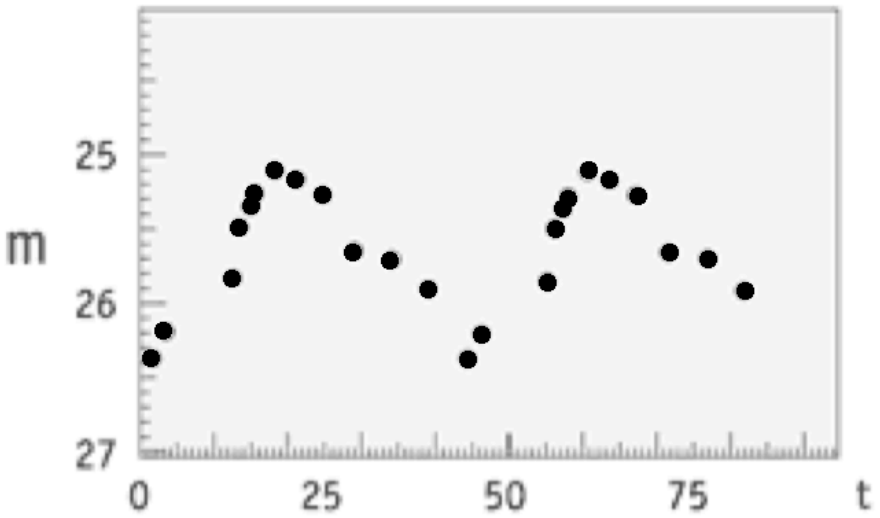
39. **(T2) Which image on image page 1 shows NGC 3582?**

40. **NGC 3582 is part of a large star-forming region. What is the designation for this region?**

41. **NGC 3582 has indicated the presence of what complex molecules?**

42. **Consider image 15 on image page 1. What *subclass* of type II supernova characterizes this object?**

M100 is a beautiful spiral galaxy in the Virgo cluster. Several light curves like the one below were produced by focusing on individual Classical Cepheid stars in the galaxy's spiral arms. This project was undertaken with the Hubble Space Telescope in the mid 1990s. The horizontal axis is in units of days. Use this light curve for questions 43 – 48.



43. What quantity is plotted on the vertical axis?

44. What is the period of this star's pulsation?

45. What is the amplitude of this star's pulsation?

46. (T9) What is this star's absolute magnitude?

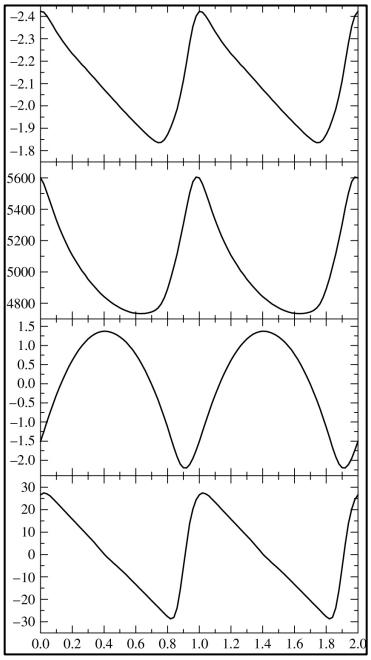
47. What is this star's luminosity, in solar luminosities?

48. What is the distance to M100, in Mpc?

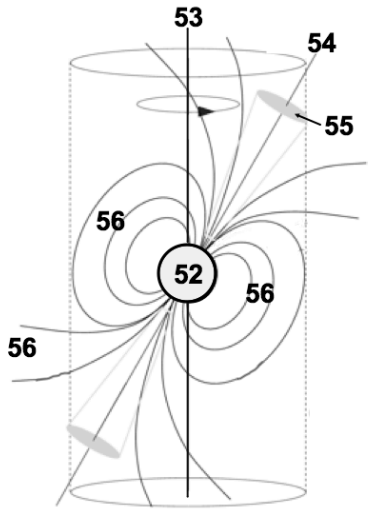
49. What is the spectral type when the star is at its brightest?

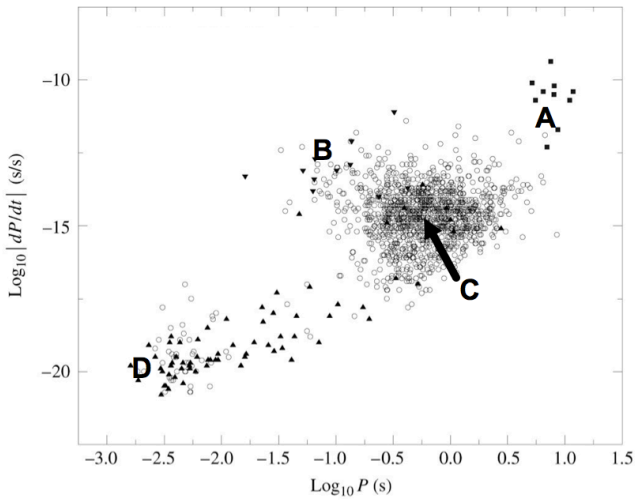
50. What is the name for the phenomenon responsible for the pulsation of Classical Cepheids?

51. The graphs shown below indicate the variation in specific quantities for δ Cephei over time. List the quantities that are shown, from top to bottom.



Consider the pulsar model shown below left. On your answer sheet, label the numbered structures. Note that #56 refers to multiple curved lines on the image.





The diagram above right shows a log-log plot of time derivative of period versus period for all pulsars for which the time derivative of the period has been determined. Use this diagram for questions numbered 57 – 60. Note that C refers to the large clump of data points.

57. What type of pulsars would be found at location A?

58. What type of pulsars would be found at location B?

59. What type of pulsars would be found at location C?

60. (T5) What type of pulsars would be found at location D?

A particular pulsar has a mass of 1.26$M_\odot$ and a radius of 12 km. It has a rotational period of 0.046 seconds and a period derivative of 1.5E-13. Assume the pulsar has uniform density. Use this information for questions numbered 61 – 65.

61. What is the rotational inertia of this pulsar?

62. What is the rotational kinetic energy of this pulsar?

63. What is the rate of rotational kinetic energy loss of this pulsar?

64. This energy loss takes the form of radio emission. What is this emission called?

65. What is the characteristic age of this pulsar, in years?

Consider the energy released in a type II supernova for questions numbered 66 - 70.

66. Supernovae typically release on the order of 10^{51} ergs of (observable) energy. What unit of measurement was devised based on this amount of energy?

67. What percent of the *total* energy is released as photons?

68. (T13) In what form is the majority of the energy released?

69. The shock wave encounters the infalling outer core and stalls. What is this called?

70. What type of gamma-ray burst is associated with core-collapse supernovae?

71. (T3) What is the defining spectral feature of Wolf-Rayet stars?

72. What is the defining spectral feature of WN stars?

73. How do most WR stars end their lives? Be specific.

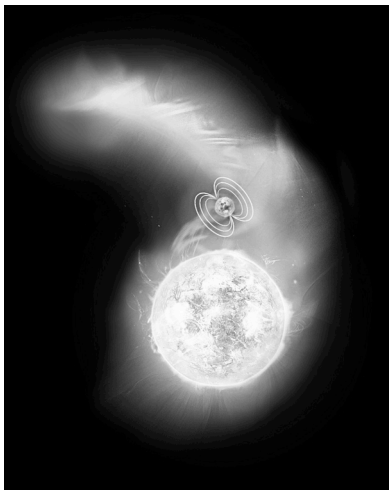
74. Why do WR stars lack hydrogen?

75. What type of star can generate an outburst known as a supernova imposter?

76. What amplitude is (arbitrarily) used to differentiate a semi-regular star from a Mira star?

77. What luminosity class characterizes main sequence stars?

Consider the binary system shown below. This is an artist's conception of Vela X-1. The normal star shown is a B0 star of 18 solar masses and 6 solar radii. The compact object shown has a mass of 1.88 solar masses and a radius of 10 km. The objects orbit each other with an orbital separation of 0.227 AU. Consider a 1.0 kg parcel of gas that originates at the surface of the B0 star with a velocity of 800 km/s and impacts the compact object some time later. The compact object emits an x-ray luminosity of 8.50E29 W. Use this information for questions numbered 78 – 84.



78. What is the orbital period of Vela X-1 in days?

79. What is the nature of the compact object?

80. How much kinetic energy will the gas have when it impacts the compact object?

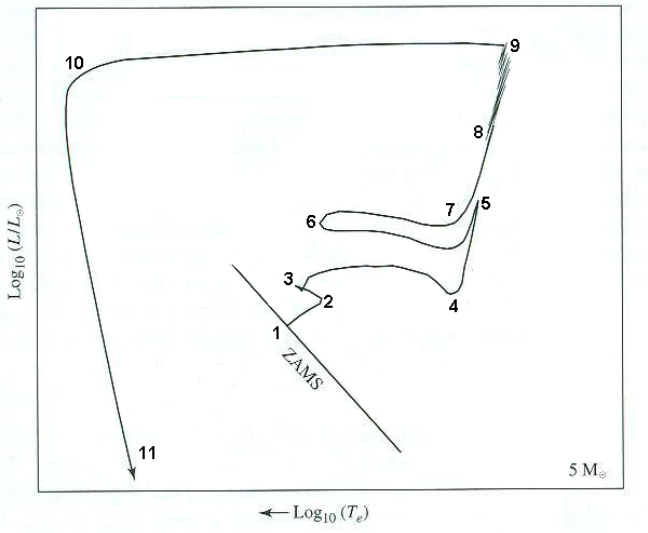
81. What percent of the speed of light will the gas have when it impacts the compact object?

82. What percent of the rest energy of the gas is represented by the kinetic energy of the gas at impact?

83. What is the mass transfer rate in kg/s, assuming all the x-ray luminosity is produced by gas pulled from the normal star?

84. (T7) How would this system be classified?

Consider the image shown below. This shows post main sequence evolution of a 5-solar-mass star. Use this diagram for questions numbered 85 – 90.



85. (T12) At which number on the graph is the red giant tip?

86. Between which 2 numbers on the graph is the horizontal branch?

87. Between which 2 numbers on the graph is the SGB?

88. At which number does the second dredge-up occur?

89. At which number do the thermal pulses in the late AGB cease?

90. Between which 2 numbers on the graph is the pre-white dwarf stage?

For questions numbered 91-100, provide the term, acronym, or phrase that best fits the description provided.

91. (T10) An abrupt change in the pulsar period

92. General relativity's prediction of distortion of the spacetime metric in the vicinity of a massive rotating object

93. The code for x-ray binaries with relativistic jets in the GCVS4

94. (T1) The upper boundary for the mass of neutron stars; neutron star analogy for the Chandrasekhar limit

95. The extent of the region of ionized hydrogen around a young O or B class star

96. (T14) Population II Cepheids with periods of 1-7 days, evolving away from the horizontal branch

97. Mass from an accretion disk around a neutron star is channeled toward the poles at this particular distance from the neutron star

98. The minimum mass necessary to initiate spontaneous collapse of a molecular cloud

99. A hypothetical object in which a captured neutron star orbits inside a giant star

100. Expanding core gas is accelerated into denser shell gas after a supernova explosion